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A Feedback Information System for Improving Hand Hygiene on a Personal and Organizational Level

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Abstract. Hand hygiene plays a key role in the prevention of infections. However, there is still a lack of hand hygiene practices among both healthcare professionals and the public. Electronic hand hygiene monitoring systems have the potential to improve the situation by giving an accurate assessment of hand hygiene behavior and by placing digital interventions, but such systems are used only in a small number of healthcare facilities. Barriers that limit their large-scale adoption include high costs, privacy concerns, and usability. In this paper, we present a novel real-time feedback system that aims to overcome the existing barriers and supports hand hygiene on a personal and organizational level.

Keywords: Hand Hygiene, Real-time Feedback, Health Information System

1 Introduction

Proper hand hygiene is one of the easiest, cheapest, and most effective ways to contain the spread of infectious diseases [1]. It is a particular concern in the health sector, where hospital-acquired infections constitute a massive threat to patient safety and cause large economic damage (average cost of 14,000$ per infection [2]) that would often be preventable. Despite large-scale efforts to improve hand hygiene practice (e.g., the “Clean Care is Safer Care” campaign by the WHO), the compliance with guidelines remains below 50% [3] and only 8.5% of healthcare workers perform correct hand hygiene technique according to guidelines [4]. The COVID-19 pandemic underlines the need for good hand hygiene outside of hospital systems and highlights the importance of hand washing everywhere, from kindergartens to elderly care facilities.

Electronic hand hygiene monitoring systems (EHHMS) can improve this situation for two reasons: First, an information system (IS) can provide a scalable, extensive, and objective method to measure and assess hand hygiene performance and identify situation- or location-specific problems. EHHMS have major advantages over human observers, as they can measure behavior permanently and less affected by the Hawthorne effect (people changing behavior due to feeling observed) [5]. Second, EHHMS can deliver digital interventions to induce behavior change towards better hand hygiene. Such interventions may comprise for instance performance feedback, “nudges” such as goal setting and the activation of social norms, and may also place reminders, which are all key elements of the WHO multimodal hand hygiene improvement strategy [6] and effective at improving hand hygiene behavior.

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We see potential in such IS that a) address barriers of adoptions that current systems face and are b) more versatile and accessible than previous systems for application areas beyond healthcare facilities. In this paper, we outline a novel IoT-based feedback IS that tracks hand hygiene behavior at the place of action only (faucet and sink for hand washing) and thereby does not rely on costly personal tracking devices. It trades more advanced tracking capabilities for a cheaper and more accessible system, while maintaining capabilities to measure and improve hand hygiene on a personal and organizational level.

2 Related Work on EHHMS

Prior research on EHHMS has mostly focused on the medical field and utilized a wide range of technologies. For instance, simple electronic soap and disinfection dispensers record frequency and time of activation, but can only inform about rough trends in hand hygiene behavior [7, 8]. More technically advanced systems use wearable tracking devices that deliver real-time feedback to improve HH compliance of healthcare workers [9–13]. This approach has led to promising results: the number of hand hygiene procedures were increased by 23% [9] and relevant nosocomial infections were halved [13]. Other systems set a focus on monitoring correct handwashing techniques which can be implemented using wristbands [14], smartwatches [15], or camera-based systems [16]. The measurement of hand hygiene behavior works well with state-of-the-art EHHMS: they detect compliance with high accuracy of over 90% [17, 18], while detection rates of hand washing poses is possible with an average accuracy of 90% for both camera based systems [16] and wrist-worn technology [15]. In addition to the papers with a technical focus, a small number of studies exist that apply concepts from behavioral economics to induce behavior change. To this work, insights from IS research may make important contributions when the objective is to build scalable yet powerful EHHMS. Examples of relevant work from IS includes studies on injunctive social norms [19], gamification in combination with social comparison [20], priming [21], and goal setting [22]. We intend to bring both fields together and build a system that allows us to test and deploy powerful interventions.

3 Methodology

We conducted an extensive qualitative screening of the literature concerning existing technical solutions, digital and behavioral hand hygiene interventions, and best practices for implementation.[1] From this literature, we identified critical barriers that limit the widespread adoption of EHHMS (see Section 3.1). To address those barriers, we derived requirements for the design of future systems (Section 3.2). The requirements are underpinned by detailed analysis of the existing literature, the

[1] The literature screening was conducted with search engines of PubMed, ScienceDirect, and Google Scholar. Search terms included e.g.: "hand hygiene AND intervention AND hospital" or “hand hygiene monitoring system”

described barriers for adoption, and interviews with major stakeholders of such systems. Unstructured and semi-structured interviews (n = 14) were conducted mostly in a one-to-one setting in German hospitals and included healthcare workers (n = 7), a hygiene officer (n = 1), clinic maintenance and building services (n = 3), engineers and salesperson from the sanitary sector (n = 3). Subsequently, we present a prototype of a feedback IS that implements the derived requirements (Section 4).

3.1 Barriers of Adoption for Previous EHHMS

Cost: Several studies have named high cost of EHHMS as a barrier for adoption [23–25]. Studies that report the costs of their EHHMS estimate them between 30000$ and 50000$ for small hospital units of 20 beds or less [9, 26, 27]. In a survey of 56 hospitals, 79.8% named cost the primary reason for non-adoption [28].
Privacy of users: Healthcare workers have expressed concerns that their location is continuously monitored using personal tracking techniques [11, 29] and data of individual hand hygiene performance might be used for punishment [29].
Usability: Systems with personal tracking devices have also been found to be inconvenient [30] and disrupt the workflow of healthcare professionals [11, 23], hence the usage of systems can decrease over time [11]. Perceived inaccuracy of tracking devices has caused frustration of users and even led to manipulation of systems [31].
Accessibility: Many systems require dedicated personal hardware (e.g. badges, wrist worn sensors, or smartwatches) and thus limit accessibility, as the systems capabilities are only available to a predefined group of users equipped with hardware.

3.2 Requirements for Our Feedback Information System

R1: *The system shall cost considerably less than previous solutions and have low operating cost.* This limits the sensors and ICT-hardware to relatively low cost versions and shifts complexity from measurement hardware to scalable software. (Barrier: Cost)
R2: *The system shall preserve privacy and not track individual behavior.* Privacy concerns are a critical barrier for the adoption of EHHMS and may lead to resistance against the introduction of such systems, especially by healthcare workers. By omitting personal tracking devices, the system emphasizes collective improvement instead of surveillance. (Barrier: Privacy)
R3: *The system shall deliver real-time feedback in situ.* Feedback has been one of the most common and effective methods in inducing behavior change. As research from other areas such as energy conservation has shown, feedback may be most powerful at changing behavior when delivered at the place of action and in real time [32]. (Barrier: Usability)
R4: *The system shall be easily integrable into existing sanitary installations.* To keep the system versatile for applications outside of healthcare, the system shall be integrated into faucets and dispensers for soap or disinfection agent. For the user, the only visible difference to a common sink is a feedback device for delivering digital interventions, which supports usability. (Barriers: Usability, Accessibility)

R5: *The system shall assure legionella prevention by automatic flushing of stagnating pipes.* Water quality plays an important role for hygiene, as Legionella reproduce in stagnating water pipes at temperatures between 25 and 45 °C and may cause pneumonia when inhaled via aerosols. Hospitals and semi-public buildings invest considerable effort into prevention and the associated documentation.
R6: *The systems (wireless) technology shall not interfere with medical equipment at healthcare facilities and drinking water regulations.*

3.3 System Architecture of Our Feedback Information System

With consideration for the identified barriers and requirements, we developed an IoT-based feedback IS for improving hand washing, as pictured in Figure 1. A single installation consists of a touchless faucet (a), a soap sensor (b), a feedback display for user interventions (c), and a gateway (d), which connects to devices (a-c) via Bluetooth and relays data to a cloud infrastructure (e). Connected IS, such as dashboards to monitor hand hygiene (f), can access the system via this cloud infrastructure.

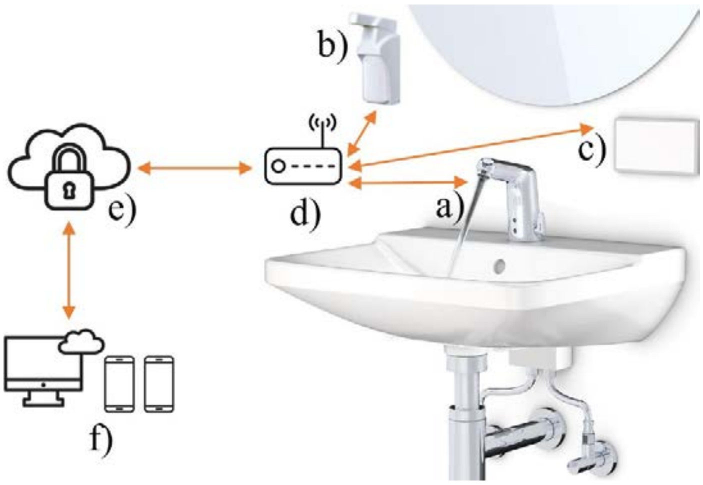

Figure 1. Architecture of our feedback information system

The system measures individual hand washing performance using the duration of the hand wash, usage of soap or disinfection agent, and the application duration of cleaning product. Thus, the adherence to the widespread five step process for hand washing [33] can be observed. We will validate the accuracy of behavior tracking with ground truth data from field experiments, which is still work in progress.
Individual users of the IS can be targeted by arbitrary messages on the feedback display, which may contain instructions, reminders, or feedback on individual behavior. To support hand hygiene on an organizational level, the system measures hand hygiene of users at all equipped faucets. Depending on the location of such faucets, this enables tracking of hand hygiene behavior across different organizational units, e.g. the wards of a hospital, or different user groups such as patients, visitors, and healthcare workers.

Such behavioral data may reveal a need for action and support resulting information campaigns for improved hand hygiene.

The lack of personal tracking hardware or vison-based technology results in some limitations of this system: Only behavior of users that interact with the installation (e.g., use of water or soap) can be tracked or influenced, while non-compliance (no hand hygiene performed) cannot be detected. Furthermore, the system is unable to differentiate between fine-grained handwashing movements and poses that e.g. vision-based systems can detect.

4 Conclusion and Outlook

EHHMS have great potential to monitor and improve hand hygiene behavior in a reliable and scalable way, but cost and complexity of existing systems limit their application to selected healthcare facilities. In this paper, we have presented a prototype of a novel IoT-based handwashing system that addresses critical adoption barriers of existing systems and supports hand hygiene on a personal and organizational level. This system is currently in development and is being evaluated in an ongoing field study with 40 installations at four hospitals and one semi-public building. In future work, we plan to use the feedback components of our system (i.e., the display next to the sink, email based reports generated by the system) to evaluate behavioral interventions (nudges such as descriptive normative feedback) targeting hand hygiene in a randomized controlled trial. Furthermore, we explore how such feedback IS can assist in forming and sustaining good habits regarding hand hygiene. With this evaluation, we aim to gather design implications for the development of future EHHMS and support a more widespread adoption in and outside of healthcare.

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